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EVALUATION OF THE U.S./CANADA WHEAT AND BARLEY EXPLORATORY EXPERIMENT SHAKEDOWN TEST ANALYST LABELING RESULTS

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16. Abstract The results of the 1980 U.S./Canada Wheat and Barley Exploratory Labeling Experiment Shakedown Test are presented in this document. This test was performed on six segments from the 1978 crop year. No major problems were found with the Reformatted Labeling Procedure as it was applied to these segments. The labeling accuracies obtained using this procedure were comparable with the labeling accuracies obtained using the Integrated Labeling Procedure. This indicates that the procedure is ready for testing with the recommended changes.					
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EVALUATION OF THE U.S./CANADA WHEAT AND BARLEY
EXPLORATORY EXPERIMENT SHAKEDOWN TEST
ANALYST LABELING RESULTS

Job Order 72-422


This report describes performance evaluation activities of the
Foreign Commodity Production Forecasting of the AgRISTARS program.

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For

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PREFACE

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a multiyear program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources, which began in fiscal year 1980. This program is a cooperative effort of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce), the Agency for International Development (U.S. Department of State), and the U.S. Department of the Interior.

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1. INTRODUCTION

The objective of the Foreign Commodity Production Forecasting (FCPF) project of the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) program is to develop and test procedures for using aerospace and related technology. Specifically, this testing and development is done to provide more objective and reliable crop production forecasts several times during the growing season and to provide improved preharvest estimates for a range of countries and crops. During the first year of the project (1980), an exploratory study of at-harvest crop proportion estimates from 1979 Landsat data for spring small grains was conducted on 5- by 6-nautical-mile segments within the northern Great Plains. To produce segment-level estimates for this experiment, analysts identify and label target pixels (dots) which are taken from Landsat imagery. Usually these dots are taken from the set of 209 pixels at the intersection of every tenth line and every tenth sample in a line.

In one procedure for labeling these dots, the analyst assimilates information from image products, spectral aids, crop calendars, and assorted meteorological and agronomic data. The analyst then subjectively applies weights to these data to arrive at a label for the dot. This method of labeling dots is part of the Integrated Labeling Procedure (ref. 1) which was used during the Large Area Crop Inventory Experiment (LACIE) and the Transition Year. The accuracy of labeling using this method depends to a great extent on the ingenuity of the analyst doing the labeling. The results can vary greatly from analyst to analyst. However, because of the subjective nature of the technique and the amount of information examined, maximum use can be made of the available data. One problem with a subjective procedure is that it is not always obvious how the label is obtained. If the label is incorrect, one can only speculate as to the reason for the error.

Because of these undesirable features, it was recognized that a more systematic and objective labeling procedure was required. If a systematic labeling procedure could be developed, the skill requirements for analysts could be reduced, the resulting labels would be less variable, and the reasons for errors would be more easily identified. In addition, the analyst activities required to produce proportion estimates for sample segments could be significantly reduced or eliminated by automation.

The Reformatted Labeling Procedure (see appendix A), for wheat and barley was developed to meet these requirements. It is based on a decision tree labeling logic. The labeling decision is obtained by answering a series of questions, with the answer to one question leading to the next question, until the end of the decision path is reached. The end point of the path determines the final label. By recording the answers to each question involved in the decision logic, it is possible to determine not only whether the label is correct but why incorrect labels were obtained.

The U.S./Canada Wheat and Barley Exploratory Labeling Experiment (ref. 2) provides the first evaluation of the labeling logic in the Reformatted Labeling Procedure. In this experiment, both the Reformatted and Integrated Labeling Procedures were used to produce dot labels using Landsat data from two crop years (1978 and 1979).

There were two tests performed in this labeling experiment. The first test (Shakedown Test) was performed using a limited number of segments from the 1978 crop year. The Reformatted Labeling Procedure was developed using data from this crop year. However, the six segments involved in the Shakedown Test were not used in developing the procedure. The main purpose of the test was to determine if there were any major problems with the procedure before it was applied in the second test to segments from the 1979 crop year. This was to be determined from the labeling accuracy and not from proportion estimation accuracy. The study of proportion estimation was the subject of a supplemental experiment.

The second test (Test 2) was designed to be a more extensive test of the procedure using data from a different crop year (1979). In this test the Integrated Labeling Procedure was applied to the same segments as the Reformatted Labeling Procedure. This provided a standard for comparison..

This report, however, presents a brief description of the procedure and the results of the first test only.

2. DESCRIPTION OF THE REFORMATTED PROCEDURE

To understand the results of this evaluation, one must have knowledge of the steps in the procedure. A detailed explanation of these steps is given in reference 2. This section will provide an outline of the procedure.

The Reformatted Labeling Procedure is based on a decision tree labeling logic which produces progressively more detailed dot labeling. The first step in the procedure is to determine which Landsat acquisitions should be used in the decision process. On the basis of crop calendar information, four acquisition windows are defined. If an acquisition is available in one of these windows, it is used in the decision process. The following list indicates the biostages corresponding to the four acquisition windows (biostage lengths are shown in parentheses).

1. pre-emergence for spring wheat (23 days)
2. spring wheat, headed (20 days)
3. barley, ripe (12 days)
4. spring wheat, harvested (15 days)

An additional window (time period A) is defined between windows 3 and 4.

The major steps in the decision logic are shown in figure 2-1. The first decision separates the spectrally pure dots from the impure dots. The impure dots are those which exhibit more than one crop signature for the acquisitions used. Dots may be impure because they are on the borders of fields or because the acquisitions are not adequately registered with each other. Only the pure dots are labeled by the procedure¹.

¹For labeling impure dots, a different approach was used. First, the pure dots were labeled. Second, through examination of the Landsat imagery, the analyst determined the field with which to associate the impure dot based on the spatial and spectral characteristics of the impure dot and adjacent fields. A comparison was then made between the multitemporal spectral signatures of the field associated with the impure dot and the fields within which pure dots had been labeled earlier. A labeling decision on the impure dot was then made on the basis of the closest subjective matching.

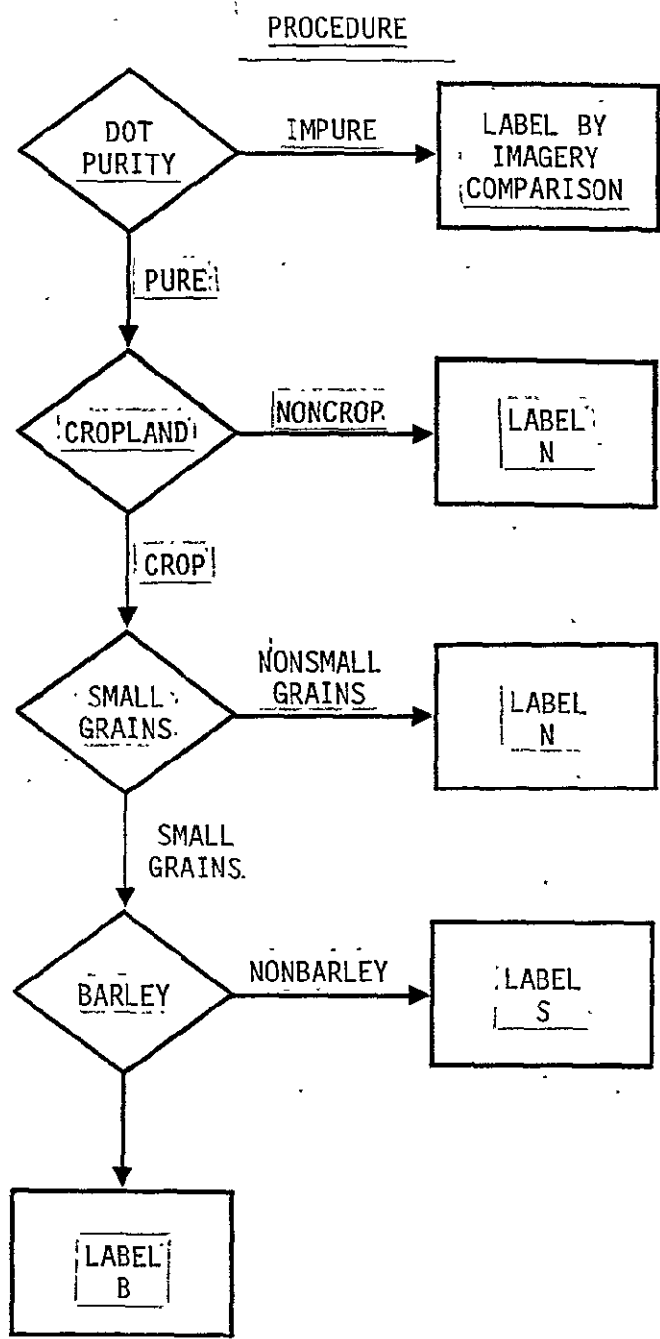
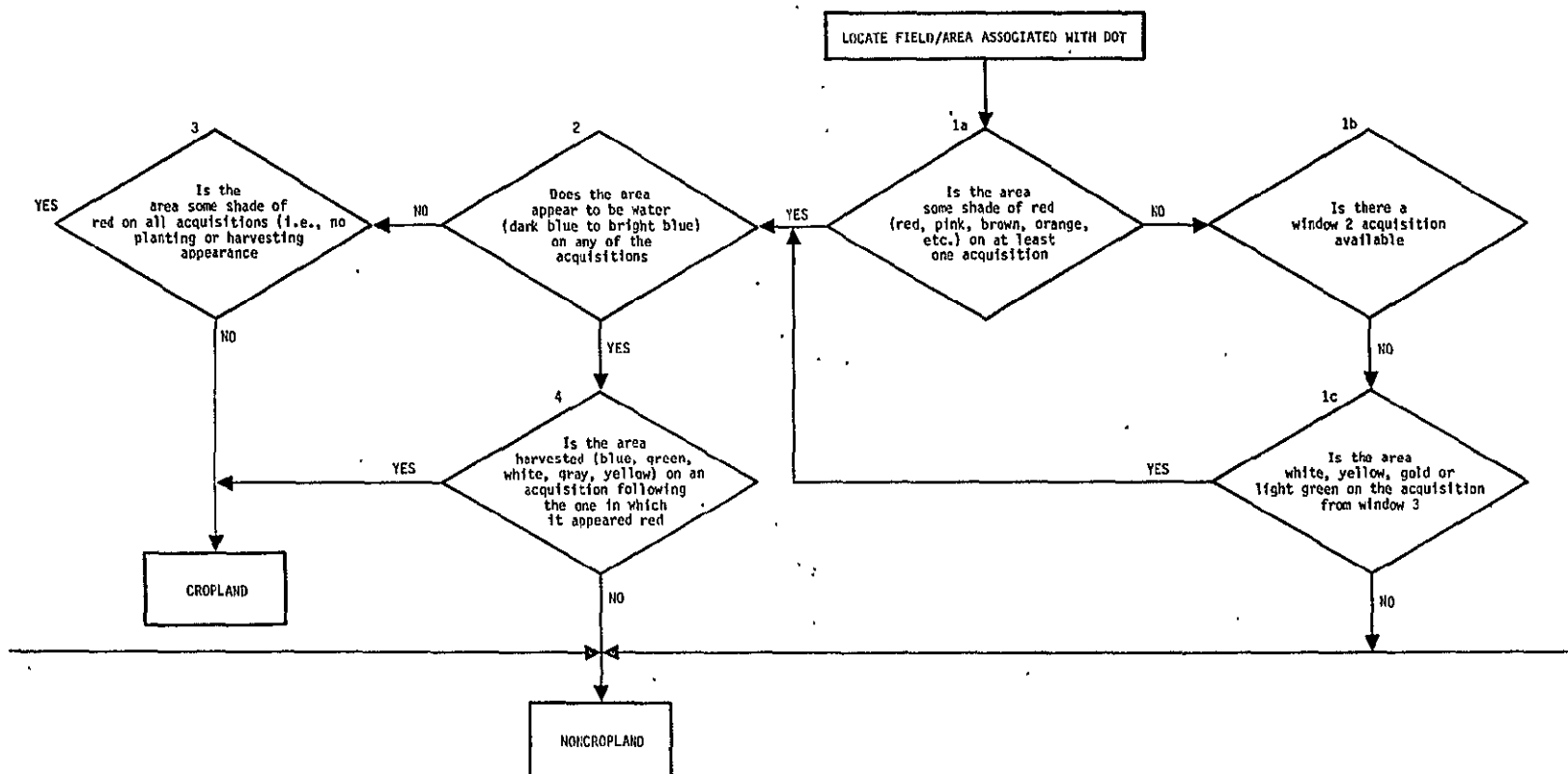


Figure 2-1.- Shakedown Test results for the reformatted procedure.

The second major step in the decision logic separates the pure dots into those with cropland signatures and those with noncropland signatures. The logic involved in this step is based on the color of the dot on the production film converter (PFC) product [figure 2-2, (ref. 3)]. The path used to arrive at the cropland/noncropland decision is defined by the answers to questions 1a, 1b, 1c, 2, 3, and 4 (see figure 2-1). The noncropland dots are labeled as nonsmall grains.

The third major step separates the dots labeled cropland into those with small grains signatures and those with nonsmall-grains signatures. The logic in this step involves the green number (refs. 4 and 5) and brightness for the dot on each of the acquisitions (figure 2-3). Each of the green number and brightness decisions is given a number so that the path taken through the decision logic can be identified.

The fourth major step separates the dots labeled small grains into those with barley signatures and those with signatures corresponding to other small grains (ref. 6). This decision is based on a green number versus brightness plot of the small grains dots for the acquisition in window 3.



2-4

Figure 2-2.- Decision logic for cropland and noncropland.

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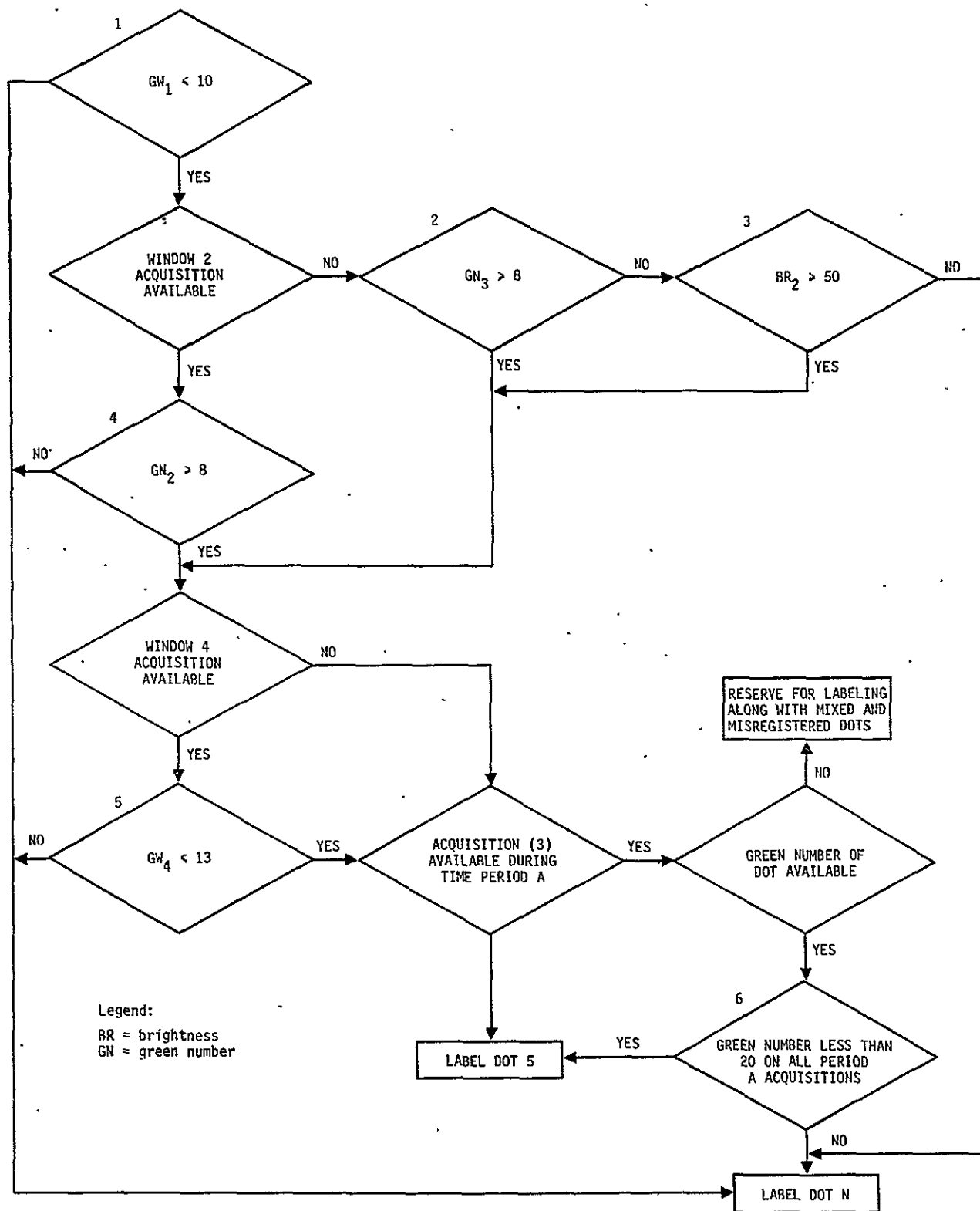


Figure 2-3.- Decision logic for pure cropland dots.

3. SHAKEDOWN TEST WITH 1978 DATA

3.1 EXPERIMENT DESIGN

In the Shakedown Test, all 209 dots for six segments were labeled using data from the 1978 crop year. The actual number of dots evaluated per segment varied downward from 209 because of clouds, cloud shadows, data dropouts, striping, or missing ground-truth inventory. The loss was a small percentage of the dots. The locations of the segments are shown in figure 3-1. Each of the segments was labeled by two analysts working independently. By comparing the two sets of labeling results, the consistency of the procedure could be evaluated. Five of these six segments were previously processed using the Integrated Labeling Procedure (ref. 7). These labeling results were used to compare the accuracy of the Reformatted Labeling Procedure with the accuracy of the Integrated Labeling Procedure.

3.2 OVERALL LABELING ACCURACY FOR FINAL LABELS

Table 3-1 shows the labeling accuracy for each of the categories labeled (non-small grains, barley, and other small grains). The labeling accuracy is shown for all the dots labeled and for those dots which were determined by the analyst to be pure, mixed, or misregistered. The labeling accuracy was greater for the pure dots (which were labeled using the decision logic) than for the impure dots (which were labeled by comparison with the pure dot labels). The numbers in parentheses show the percentage of dots correctly labeled when both analysts agreed on the label. The labeling accuracies were, in general, greater when there was agreement between the analysts.

Table 3-2 shows a comparison, on a segment-by-segment basis, between accuracy obtained using the Reformatted Labeling Procedure and that obtained using the Integrated Labeling Procedure. Overall, the Reformatted Labeling Procedure produced labeling accuracies which were comparable to the accuracies for the Integrated Labeling Procedure. For some segments, the Reformatted Labeling Procedure obtained better results in certain categories than did the Integrated Labeling Procedure, while on other segments, the reverse was true.

TABLE 3-1.- ANALYST LABELING ACCURACY

[Percent correctly labeled]

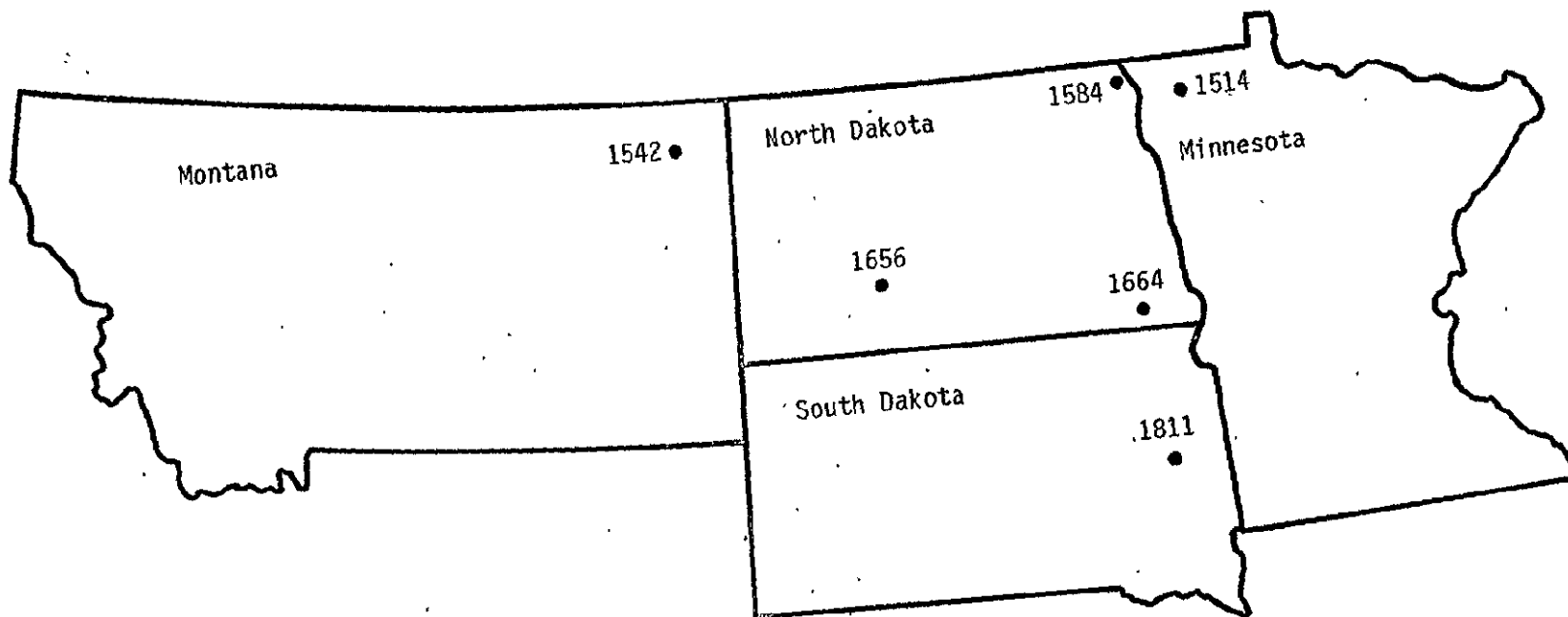
Crop category	All dots	Pure dots	Mixed dots	Misregistered dots
Nonsmall grains	91(95)	94(97)	73(78)	82(91)
Small grains (except barley)	72(82)	74(84)	66(83)	55(63)
Barley	51(49)	50(51)	60(-)	50(-)
Total small grains	77(86)	79(87)	73(86)	67(76)

Note: The numbers in parentheses show the percentage of dots correctly labeled when both analysts agreed on the label.

TABLE 3-2.- SEGMENT-LEVEL RESULTS FOR SHAKEDOWN TEST

Segment number	Procedure	Correctly labeled dots, %			Segment A characteristics
		Small grains	Barley	Nonsmall grains	
1542	Reformatted	91	-	93	25% small grains (no barley)
	TY	42	-	96	3% other crops
1584	Reformatted	86	44	88	50% small grains 11% barley
	TY	93.4	45	94	Acquisitions deficient for barley
1656	Reformatted	57	-	95	75% noncropland 7% small grains
	TY	52.6	-	97	No barley
1664	Reformatted	70	81	95	38% small grains 8% barley
	TY	87	54.5	94	27% other crops
1811	Reformatted	56	36	81	25% small grains 2% barley
	TY	70	0	94	40% other crops
Overall	Reformatted	76	52	91	
	TY	75	55	95	

Note: Segment 1514 was not processed during the TY.



3-4

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Figure 3-1.- Locations of segments used in the Shakedown Test.

The barley labeling accuracy was not very high for either procedure, with only half of the barley being labeled correctly. However, the segments involved in this test had an average barley proportion of only 5 percent, with two segments containing no barley at all. Because of the nature of the barley/other-small-grains labeling technique, the labeling accuracy for barley cannot be adequately tested if a reasonable amount of barley is not present. Therefore, in all of the subsequent discussions, barley is considered part of the small-grains category, and labeling accuracies are evaluated for small-grains/nonsmall-grains labeling only.

The labeling accuracies for individual crops are shown in table 3-3. None of the nonsmall grain crops were consistently mislabeled, and of the small-grains crops, only flax was incorrectly labeled more often than it was correctly labeled. [This type of labeling error for flax² was observed in LACIE Phase III (ref. 8) and the Transition Year (ref. 9). Because there is so little flax, it is difficult on the basis of these and prior results to decide whether flax should be identified as a small grain or as a nonsmall grain.]

3.3 CROPLAND/NONCROPLAND LABELING ACCURACY

The labeling accuracy for the cropland/noncropland decision logic is shown in table 3-4. The dots considered in evaluating the cropland/noncropland labeling accuracy were those which the analyst had decided were pure. The labeling accuracy obtained as a function of the path taken through the decision logic is also shown in table 3-4. None of the paths through the decision logic consistently produced wrong answers. It should be noted that an affirmative response to question 1a occurred 84 percent of the time. In those instances when an affirmative was given, question 3 became the decision maker. While the labeling accuracy for the dots following this path which received a noncropland label was consistent with the labeling accuracies for other pathways leading to a noncropland label, the labeling accuracy for the dots following this path which received a cropland label was lower than the labeling accuracy

² Although flax is not a small grain, its spectral signature is similar and is considered as grouped with the small grains.

TABLE 3-3.- ANALYST LABELING ACCURACY FOR
INDIVIDUAL CROPS

Crop	Number of dots labeled	Crops correctly labeled, % (nonsmall grains or small grains)
Nonsmall grains:		
Alfalfa	58	81
Corn	155	78
Sunflower	109	92
Sugar beets	14	79
Grass	112	93
Hay	137	91
Pasture	539	95
Trees	12	83
Water	34	94
Nonagricultural	111	96
Homestead	23	87
Idle	257	89
Small Grains:		
Spring barley	111	83
Spring wheat	443	81
Flax	34	41
Spring oats	92	62
Duram wheat	16	100

TABLE 3-4.- LABELING ACCURACY FOR CROPLAND/NONCROPLAND

(a) Overall labeling accuracy

Crop type	Correctly labeled dots, %
Cropland	84(90)
Noncropland	74(82)

(b) Accuracy by path through the decision logic

Answers to questions						Labeling decision	Total dots labeled, %	Correctly labeled dots, %	Crops which most frequently produce errors
1a	1b	1c	2	3	4				
Y	-	-	N	N	-	Crop	52	77(85)	Grass, pasture, nonagricultural, idle
Y	-	-	N	Y	-	Noncrop	32	82(86)	Alfalfa, corn, spring wheat, barley
N	Y	-	-	-	-	Noncrop	9	84(95)	Spring wheat, barley
N	N	Y	N	N	-	Crop	3	90(92)	Idle
N	N	N	-	-	-	Noncrop	2	85(-)	Spring wheat

Note: The numbers in parentheses reflect the percentage of labeled dots when both analysts agreed on the label.

of the other pathway leading to a cropland label. Because 66 percent of the areas of these segments was cropland and because the labeling accuracy for the dots labeled cropland by decision 3 was lower than the labeling accuracy for the dots labeled noncropland, it can be seen that there were more noncropland dots incorrectly labeled than there were cropland dots incorrectly labeled. This, however, presents no later problem since the incorrectly labeled noncropland dots remain in the flow of the decision logic. They may still be labeled nonsmall grains. In fact, for this reason if one of these categories were to have a low labeling accuracy, it would be better that it be for the dots labeled cropland. Thus, the fact that the labeling accuracy for the dots labeled cropland is lower than the labeling accuracy for dots labeled noncropland is not disturbing. There did not appear to be any major problems with the cropland/noncropland decision logic.

3.4 SMALL GRAINS/NONSMALL GRAINS LABELING ACCURACY

Table 3-5 shows the labeling accuracy for the small-grains/nonsmall-grains decision logic. The dots used in evaluating the small-grains/nonsmall-grains labeling accuracy are those which were correctly identified as cropland by the analyst. The accuracy for this logic appears to be quite good, especially when there is agreement between the analysts on the label. From the table 3-5(b), accuracy as a function of path through the decision logic, it can be seen that a wide variety of paths through the logic are used. None of the paths appear to produce consistently incorrect answers. This would indicate that there are no major problems with the logic.

As stated previously, there was not enough barley in these segments to determine if the barley separation procedure was working properly. However, the accuracy in separating barley from other small grains is presented in table 3-6. The dots used to determine this accuracy are those which were correctly labeled as small grains by the analyst. Only about half of the barley is correctly labeled, while almost all of the other small grains are labeled correctly.

TABLE 3-5.- LABELING ACCURACY FOR SMALL GRAINS/NONSMALL GRAINS

(a) Overall labeling accuracy

Crop type	Correctly labeled dots, %
Small grains	88(94)
Nonsmall grains	89(92)

(b) Accuracy by path through the decision logic

Answers to questions						Labeling decision	Total dots labeled, %	Correctly labeled dots, %	Crops which most frequently produce errors
1	2	3	4	5	6				
Y	-	-	Y	-	Y	SG	22	94(96)	Corn, sunflower
Y	Y	-	-	N	-	NSG	15	73(78)	Spring wheat
Y	Y	-	-	-	Y	SG	13	97(98)	Hay
Y	-	-	Y	Y	Y	SG	10	94(95)	Sunflower
Y	Y	-	-	-	N	NSG	7	84(100)	Spring wheat
Y	Y	-	-	Y	Y	SG	6	88(90)	Corn
Y	-	-	Y	-	N	NSG	6	92(95)	Spring wheat
Y	Y	-	-	Y	-	SG	6	95(100)	-
N	-	-	-	-	-	NSG	5	81(87)	Spring oats
Y	N	N	-	-	-	NSG	3	95(100)	-

Note: The numbers in parentheses reflect the percentage of correctly labeled dots when both analysts agreed on the label.

NSG = nonsmall grains

SG = small grains

TABLE 3-6.- LABELING ACCURACY
FOR SMALL-GRAINS/BARLEY
DISCRIMINATION

Crop type	Correctly labeled dots, %
Small grains (except barley)	95(98)
Barley	61(54)

3.5 CONSISTENCY OF ANALYST LABELING

One of the important requirements for an objective labeling procedure is that it be consistent. In the Shakedown Test, each of the dots was labeled independently by two analysts. By comparing the results obtained by each of the analysts, the consistency of the procedure can be investigated. The first decision the analyst must make is whether the dot is pure or not. The results of this test showed that the analyst agreed on whether the dot was pure 77 percent of the time. The analysts agreed on the final label for the dot 85 percent of the time. Table 3-7 shows the consistency for the major steps in the procedure. Each of the percentage consistencies is based on those dots which were consistently labeled at the previous major step. The most interesting feature of these results is that the labeling is more consistent for pure dots (when the decision logic is used) than for mixed dots (which are labeled by comparison with pure dot labels).

3.6 RECOMMENDATIONS FOR CHANGES TO THE REFORMATTED PROCEDURE

The results of this test indicated that there were no major problems with the Reformatted Labeling Procedure. However, in order to determine if there could be some improvements to the procedure, an error characterization study was performed on the labeling from this test. The general conclusions from this study were that the consistent errors were due to atypical signatures and that there were no specific confusion crops. The error characterization did provide some suggestions for changes which would improve the procedure and reduce the chances of clerical error.

One of the most important recommendations concerned the handling of nonpure pixels. In the Reformatted Labeling Procedure, these pixels were reserved for labeling by imagery comparison after the pure pixels were labeled. This test showed that the labeling accuracy and consistency for these reserved pixels was less than for the pure pixels. Because of this difference, it was suggested that (if possible) the analyst should determine from the imagery which field to associate with the mixed pixel. Then a pure pixel should be designated in the field associated with the mixed pixel. The label for the mixed pixel could be

TABLE 3-7.- CONSISTENCY OF LABELING AS A FUNCTION OF
DECISION LOGIC STEP

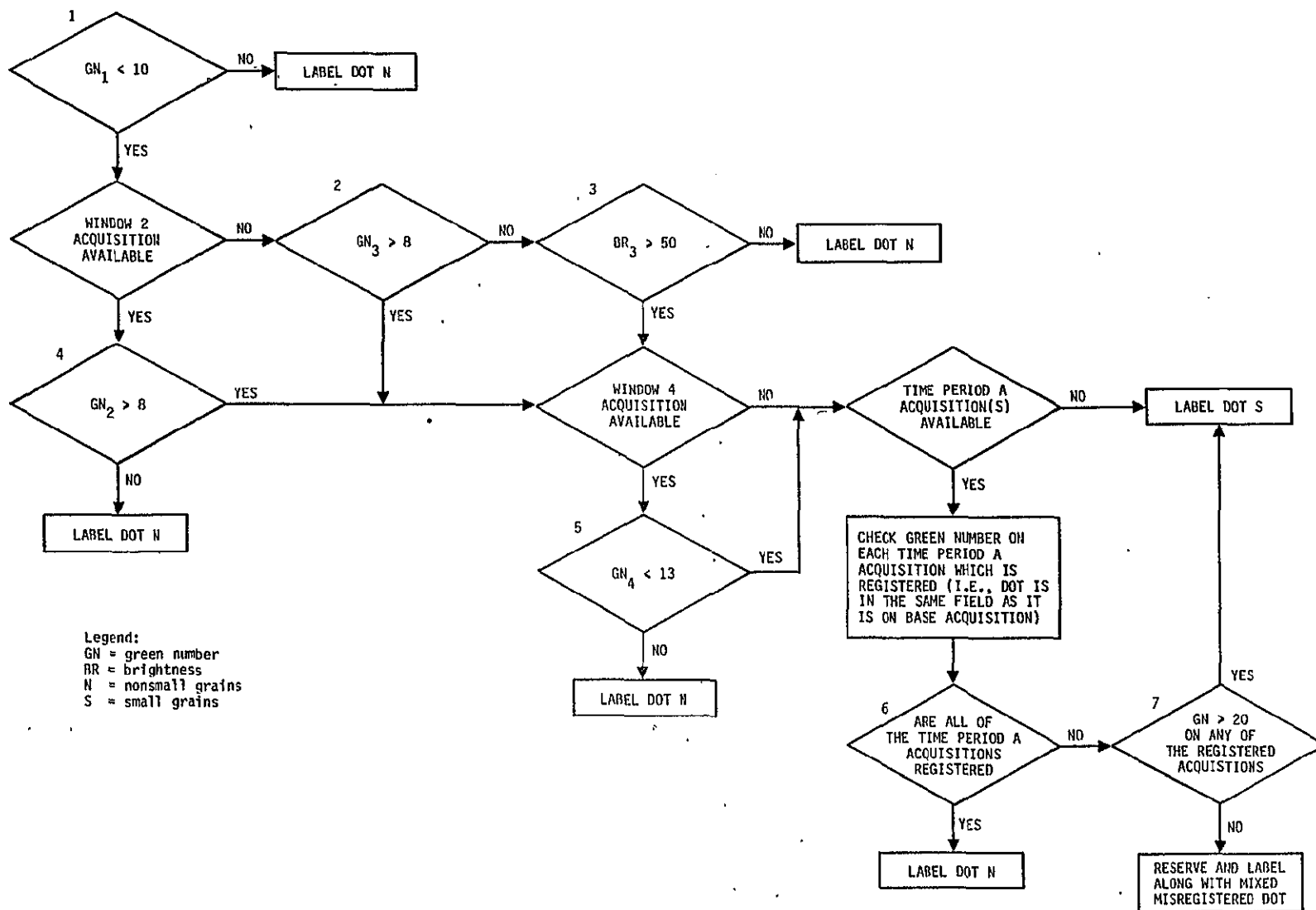
Decision logic step	Consistent labels, %		
	Overall	Pure dots	Mixed dots
Cropland/noncropland	80	85	48
Small grains/nonsmall grains	85	95	76
Small grains/barley	92	94	86

determined by applying the decision logic to the pure pixel associated with it. This should increase the labeling accuracy of the pure pixels associated with the mixed pixels to the same level as for the pure pixels.

Another recommendation involved question 3 of the cropland/noncropland decision logic. This question determined the cropland/noncropland decision 84 percent of the time and exhibited a lower labeling accuracy than did other paths. In addition, there was a certain amount of inconsistency in answering this question. The question asks whether the pixel is some shade of red on all acquisitions. It was recommended that the question be expressed in terms of the green number for the pixel rather than in terms of color on the imagery. This should make the question more objective.

Recommendations were made for improving the clarity of the procedure and reducing clerical errors. In particular, the use of the time period A acquisitions in the small-grains/nonsmall-grains decision logic was not clear in the original procedure. Figure 3-2 shows the logic after it was revised to make use of the time period A acquisitions clearer.

A number of review steps and internal consistency checks were incorporated into the label recording forms. This should help to eliminate clerical errors from the labeling process.



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Figure 3-2.- Labeling logic for small grains/nonsmall grains.

4. CONCLUSION

The results from the Shakedown Test indicated that there were no major problems with the Reformatted Labeling Procedure as it was applied to the segments involved. The labeling accuracies were comparable with the accuracies for the Integrated Labeling Procedure.. Though this performance needs to be verified through more extensive testing, the reformatted procedure does represent a substantial automation of the labeling process. With the recommended changes to the procedure, the Reformatted Labeling Procedure should be ready for testing on 1979 data.

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APPENDIX A

DEVELOPMENT OF AN ENHANCED BASELINE SPRING SMALL GRAINS PROCEDURE

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A SUBSIDIARY OF
LOCKHEED CORPORATION

1830 NASA Road 1, Houston, Texas 77058
Tel. 713-333-5411

Company, Inc.

December 20, 1979
Ref: 644-1472
Job Order 74-413
NAS9-15800

Mr. R. M. Bizzell, SF4
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas 77058

Dear Mr. Bizzell:

Subject: Development of Enhanced Baseline Spring Small Grains Procedure
AD 63-2137-4413-01

The attached document describes the development of the procedure which was produced under action document 63-2137-4413-01. The final revision of this procedure is included as the appendix.

Copies of the preliminary draft were delivered to the task monitor on November 19, 1979. Copies of the first revision, which incorporated reviewers' comments, were delivered to the NASA analysts on December 3, 1979, before the start of the shakedown test. Additional changes for clarification have been included in this final revision.

All work on this task has been completed.

Concurrence:

Sincerely,

B. L. Carroll
for W. G. Baron, Project Manager
TY SF4 Project Office.

W. F. Palmer
W. F. Palmer

Approval:

Attachment

cc: JSC/L. F. Childs, SF2 (w/o attach.)
J. L. Dragg, SF4
G. Gutschewski, SF3
R. O. Hill, SF4
A. G. Houston, SF4
L. C. Wade, SF4
LEC/B. L. Carroll *etc*
J. J. Vaccaro (w/o attachment)
Job Order File

Luis M Flores
L. M. Flores, Supervisor
Design Integration Section

DEVELOPMENT OF THE
REFORMATTED SPRING SMALL GRAINS LABELING PROCEDURE

Objective

The objective of this effort was to develop a procedure for labeling small grains and barley in the northern U.S. Great Plains segments by converting the U.S. spring small grains and barley separation procedure used during the Transition Project to a format similar to the corn/soybeans decision logic (Ref.). The techniques that were used in the Transition Project were to be enhanced whenever possible.

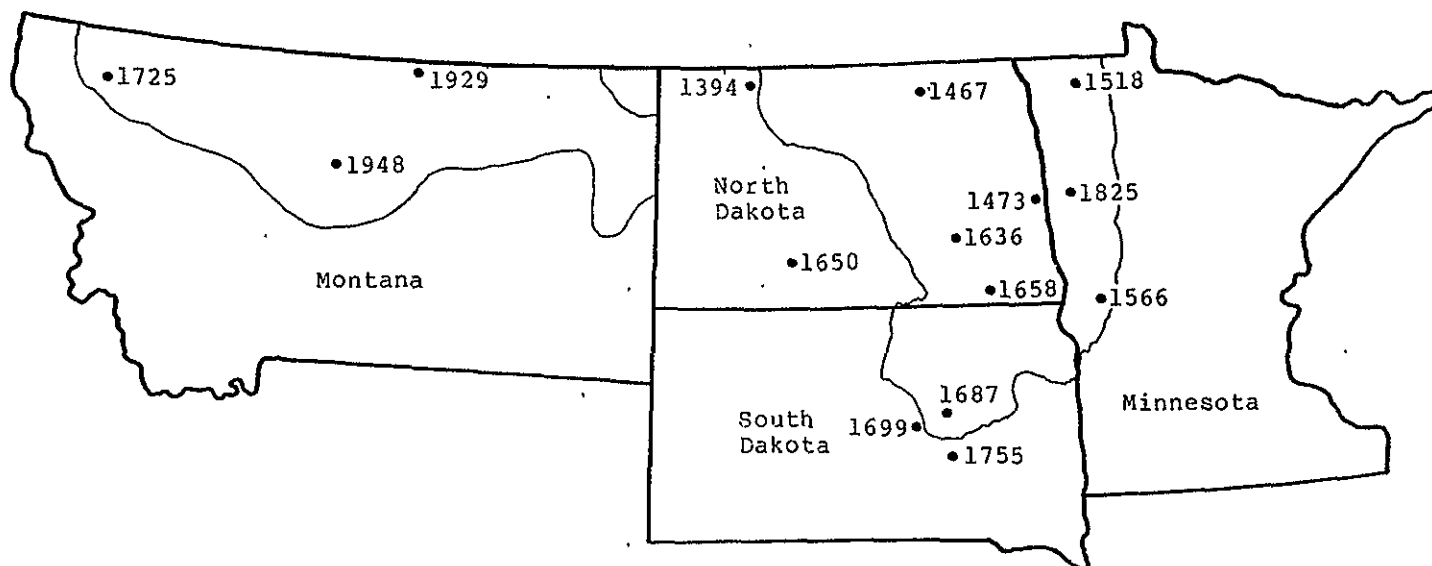
Approach

Following a comprehensive review of the Transition Project labeling procedures, alternative methods for performing some of the steps were identified. These alternatives were designed to leave fewer subjective analyst decisions in the labeling process.

The new techniques were tested using segments from the developmental data set. Necessary modifications and revisions were made before incorporating them into the overall labeling procedure.

Developmental Data Set

The labeling procedure is based primarily on analysis/observations of the segments shown in figure 1 which comprised



North Dakota	1394	1978 Blind site
	1467	1978 Blind site
	1636	1978 Blind site
	1473	1978 Blind site
	1650	1978 Blind site
	1658	1978 Blind site
Minnesota	1518	1978 Blind site
	1825	1977 and 1978 Blind site
	1566	1978 Blind site
South Dakota	1687	Intensive test site
	1755	1978 Blind site
	1699	1977 Blind site
Montana	1725	1977 and 1978 Blind site
	1948	1977 and 1978 Blind site
	1929	1977 Blind site

Figure 1.- Developmental data set.

the developmental data set. Shaded areas on the map represent the major barley producing regions of each state.

Criteria for selection of the segments were based upon having a sufficient number of acquisitions to adequately describe the growth cycle of spring small grains and having a reasonably large proportion of spring small grains, particularly barley.

In South Dakota and Montana, an Intensive Test Site and two phase two blind sites were used in order to obtain segments which were suitable for labeling procedure development.

Discussion of the Procedure

There are essentially three major divisions within the labeling procedure (appendix A1). These are 1) the separation of dots into either cropland or non-cropland, 2) the separation of cropland dots into spring small grains or non-spring small grains, and 3) the separation of spring small grains dots into barley or other spring small grains.

For the cropland/non-cropland separation, the procedure relies on a slightly modified portion of the Decision Logic for Major Land-Use Categories which was developed as part of the corn/soybeans procedure.

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Since segments can be processed without an acquisition during the time when barley is green vegetation, the first major division had to be modified to insure that barley would be labeled cropland.

Additionally, when responses are such that the decision is clearly non-cropland, the dot (pixel) is labeled instead of attempting a further breakdown into range, forest, etc.

The successful identification of spring small grains is usually the result of an analyst being able to select acquisitions on which certain fields appear to follow the predetermined crop growth stage pattern of spring small grains (e.g., all spring small grains are bare soil, all spring small grains are green vegetation, etc.). If the coupling of two or more of these acquisitions provides a unique "signature" for spring small grains (e.g., bare soil on acquisition 1 and green vegetation on acquisition 2), accurate labeling should result.

In order to proceduralize this process, a window technique was devised to select acquisitions on which the appearance of spring small grains would be predictable. The expected characteristics of spring small grains on acquisitions selected from each window are presented in table 1.

If the proper acquisitions are selected, a description of the expected appearance of spring small grains as a function of

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TABLE 1.- EXPECTED CHARACTERISTICS OF ACQUISITIONS
AS A FUNCTION OF WINDOW

Window	Description of spring small grains	Product 1 appearance of spring small grains
1	<p>Plowing/planting for spring small grains</p> <p>All spring small grains appear to be bare soil</p> <p>Spring wheat Robertson stage 0.8 - 2.4</p>	<p>Light to dark green, light to dark gray, black</p>
2	<p>All spring small grains appear to be green vegetation. (Most of the summer crops appear to be bare soil.)</p> <p>Spring wheat Robertson stage 3.8 - 4.5</p>	<p>Red, pink, brown orange</p>
3	<p>Spring barley is turned/harvested and spring wheat, oats, and flax appear to be green vegetation</p>	<p>Deep red, reddish brown, brown, orange, pink, yellow, gold, olive, white, gray, green</p>
4	<p>Spring wheat Robertson stage 4.7 to beginning of harvest</p> <p>All spring small grains appear to be turned/harvested.</p>	<p>Light to dark green, light to dark gray, white, yellow, gold, olive, black</p>

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window should allow accurate separation of spring small grains from non-spring small grains. In an attempt to provide a more objective description of appearance, green numbers and brightness were used in lieu of color descriptions for this procedure.

Observation of the behavior of the green number/brightness of spring small grains on segments from the developmental data set was used to establish the green number/brightness criteria for spring small grains as a function of acquisition/window. These cutoffs were utilized in the decision logic for spring small grains.

For the separation of barley and other spring small grains, much of the transition project labeling procedure was retained. However, there are several important modifications including the following:

- 1) The separation acquisition is selected using an objective procedure. This is the window 3 acquisition.
- 2) The decision boundary on the green number versus brightness scatter plot is a straight line with fixed slope.
- 3) The concept of dot drift is introduced to assist in determining the location of the decision boundary. Dot drift is the direction of movement in the green number-brightness plane from the window 2 acquisition to the window 3 acquisition.

Minimum Acquisition/Window Requirements

The definition of a minimum data set for processing segments with this labeling procedure reflects extensive LACIE experience in addition to observations of the segments from the developmental data set.

A window 1 acquisition was known to be a requirement in mixed wheat areas to provide separation between winter and spring small grains. This requirement was extended to all of the areas of interest because of its additional value for separating natural vegetation.

An acquisition in window 2 or window 3 is required to provide a date when spring small grains are growing. Since the barley separation technique relies on observing barley turning/harvested while the other spring small grains are pre-turning, a window 3 acquisition is required to execute that portion of the procedure.

An acquisition in window 4 is essential in areas such as South Dakota and Minnesota to avoid confusion between summer crops such as corn and spring small grains.

APPENDIX A1

REFORMATTED SPRING SMALL GRAINS LABELING PROCEDURE

The reformatted spring small grains labeling procedure is designed to be used for assigning labels to a pre-determined selected number of dots. Spectral data or statistics from these dot labels may be used as input to a machine classification/clustering algorithm.

The general flow of the steps involved in the procedure is detailed in the diagram in figure 1. Following acquisition selection (step 1), the combination of acquisitions/windows available are considered to determine the type of labeling, if any, that can be performed using the procedure.

If the available acquisitions/windows are sufficient for barley separation, the entire procedure can be executed. If an acquisition from window 3 is not available, only the spring small grains portion (steps 4 through 7) of the procedure can be used.

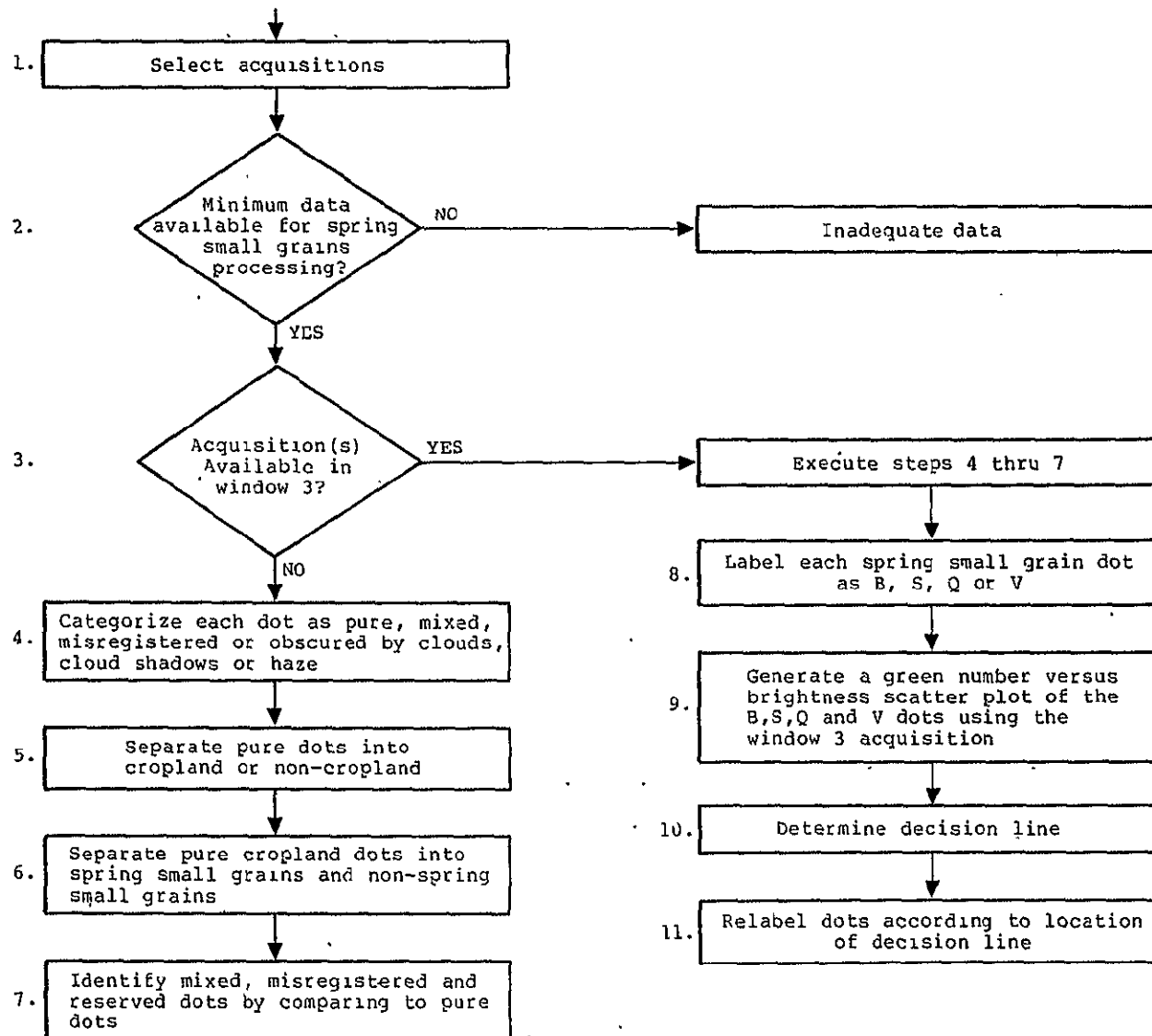


Figure 1.- Flow Diagram of Reformatted Spring Small Grains Labeling procedure.

Reformatted Spring Small Grains Labeling Procedure

1. Select Acquisitions

Using the historical crop calendars for spring wheat and spring barley, determine the opening and closing dates for each of the following four windows:

Window	Open	Close
1	Spring Wheat 50% Planted -5 days	Spring Wheat 50% Planted +18 days
2	Spring Wheat 50% Headed -10 days	Spring Wheat 50% Headed + 10 days
3	Spring Barley 50% Turning to Ripe - 6 days	Spring Barley 50% Turning to Ripe + 6 days
4	Spring Wheat 50% Harvested + 15 days	Spring Wheat 50% Harvested + 30 days

Sort all available acquisitions covering the growing season for spring small grains (beginning of planting to one month after the completion of harvest) into these windows.

Select one acquisition per window. If more than one acquisition falls within a window, select the one closest to the middle of the window. If two acquisitions are equidistant from the middle, select the latest one.

If a window does not contain an acquisition but one falls within three days of the opening or closing of the window, refer to the adjusted crop calendar, meteorological summaries and location of the segment within the crop reporting district to determine whether or not the acquisition should be included in the window.

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For example, if an acquisition falls three days after the close of a window and the adjusted crop calendar/meteorological summaries indicate that in the area of the segment spring small grains are late developing or the segment is in the northernmost part of a large crop reporting district, include the acquisition in the window.

In a similar manner, acquisitions falling within three days of the start or end of a window may be excluded from the window. Suppose an acquisition is collected two days before the close of window 1 and the adjusted crop calendar/meteorological summaries indicate that spring small grains development is considerably ahead of normal in the area of the segment. The analyst should select another acquisition or if there are no other candidates, conclude that no window 1 acquisition exists.

If available, the window 3 acquisition is to be used as the base acquisition for labeling. If there is no window 3 acquisition, use the window 2 acquisition. If neither of these windows contain an acquisition, the segment is unprocessable.

Screen the base acquisition for data quality. If the acquisition contains excessive ($>40\%$) clouds, cloud shadows, haze or snow or other problems such as data dropouts, banding, etc., revert to the second choice for the base acquisition. If data quality on the second choice is unacceptable, revert to the third choice. Continue until a base acquisition with

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with acceptable data quality has been selected or the list of candidates has been exhausted.

Screen each of the other selected acquisitions for data quality using the same criteria plus registration to the base acquisition to \pm one pixel. In each case, if the acquisition fails the data quality test, revert to the second choice, third choice, etc. until an acceptable acquisition has been found or the candidates have been exhausted.

The decision logic for spring small grains requires the use of acquisition(s) in addition to those previously selected if available.

Acquisitions collected within the time period beginning with the close of window 3 plus 40% of the distance between the close of window 3 and the opening of window 4 and ending with the opening of window 4 are described as being in time period A. This period is graphically described in Figure 2.

The acquisitions selected and the time period A acquisitions should be recorded on the acquisition form as shown in Figure 3. The format of year, day should be used. 8124 indicates the 124th day of 1978.

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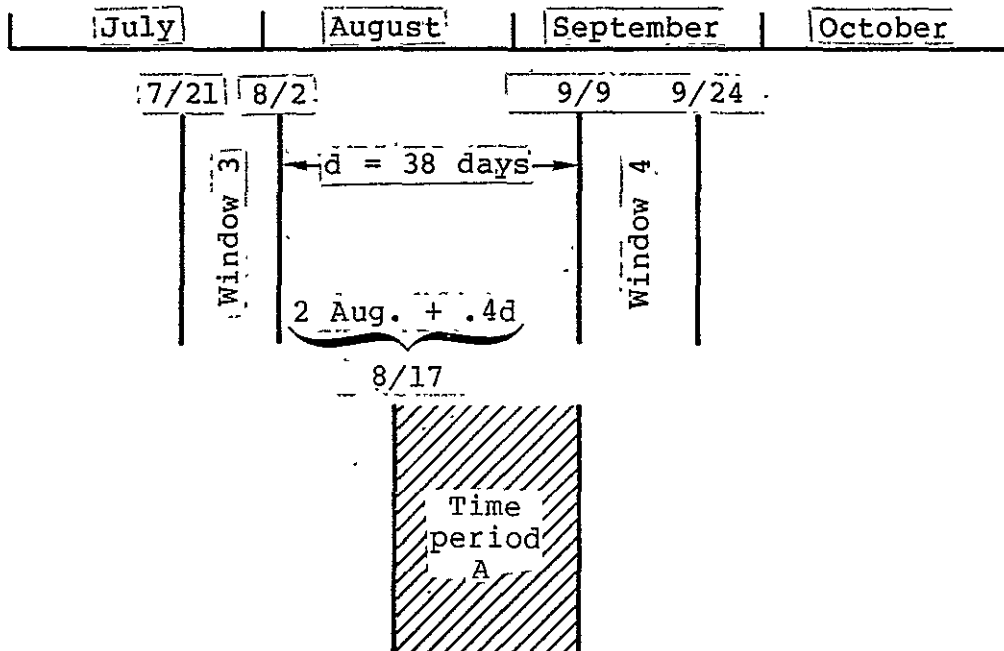


Figure 2.- Graphical description of the determination of time period A.

SEGMENT NUMBER	ACQUISITIONS SELECTED FROM WINDOWS																ACQUISITIONS COLLECTED DURING TIME PERIOD A																										
	WINDOW 1				WINDOW 2				WINDOW 3				WINDOW 4				ACQ. 1				ACQ. 2				ACQ. 3																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
1	1	8	2	5		8	1	2	4		8	1	8	7		8	2	0	6		8	2	5	1		8	2	2	3		8	2	2	4		8	2	3	2				
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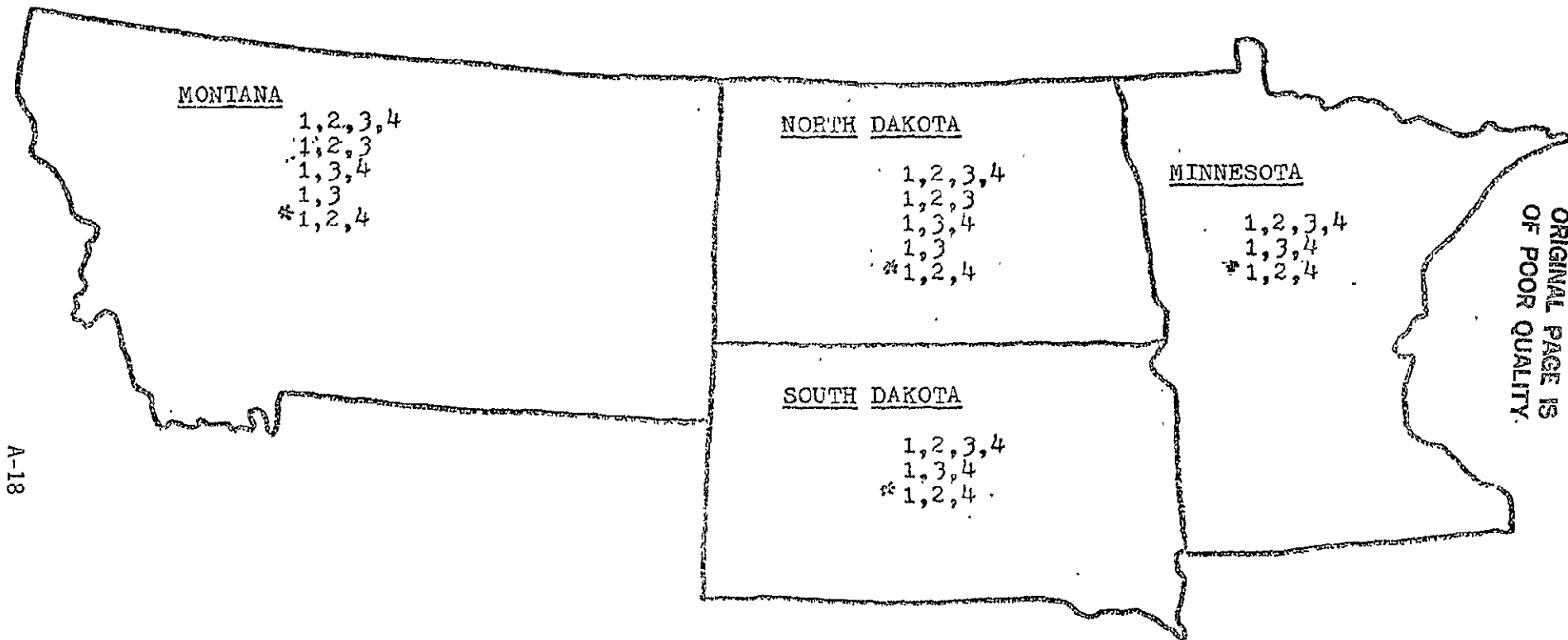
Figure 3.- Acquisition Recording Form.

2. Check for Minimum Data

Refer to the map in Figure 4 to determine if the combination of windows/acquisitions available meet the minimum requirements for processing. If the combination available is not listed as a processable data set, there is inadequate data for spring small grains labeling using this procedure.

3. Check for minimum data for barley separation

The barley separation procedure is based on the assumption that barley ripens and is harvested before spring wheat, oats and flax. The acquisition selection process for selecting the window 3 acquisition is intended to isolate the acquisition where this difference is maximized. Therefore, an acquisition in window 3 is required for this procedure.



* Inadequate for barley separation. Spring small grains labeling only.

Figure 4. Processable Data Sets.

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4. Categorize each dot as pure, mixed, misregistered or obscured by clouds, cloud shadows or haze.

The following definitions are used in this step:

Pure dot - A dot which is completely within the same field/area on each of the selected acquisitions.

Mixed dot - A dot which is only partially within a field/area on the base acquisition.

Misregistered dot - A dot which is completely within a field/area on the base acquisition but shifts either partially or completely out of the field/area on one or more of the selected acquisitions.

Using the base acquisition, locate the field/area associated with the dot of interest. If the pixel is not the same color as the field/area it is associated with, the dot should be considered mixed. For example, in Figure 5, the dot of interest is associated with field A, a white field. If the pixel at this location appears pink rather than approximately the same color as the other pixels in field A, the dot should be considered mixed.

If the dot is not mixed, the same test should be applied to the pixel at this location on each of the remaining selected acquisitions. If the dot shifts partially or completely to another field, it should be considered misregistered. If the dot remains completely within the same field/area on all of the selected acquisitions, it should be considered pure.

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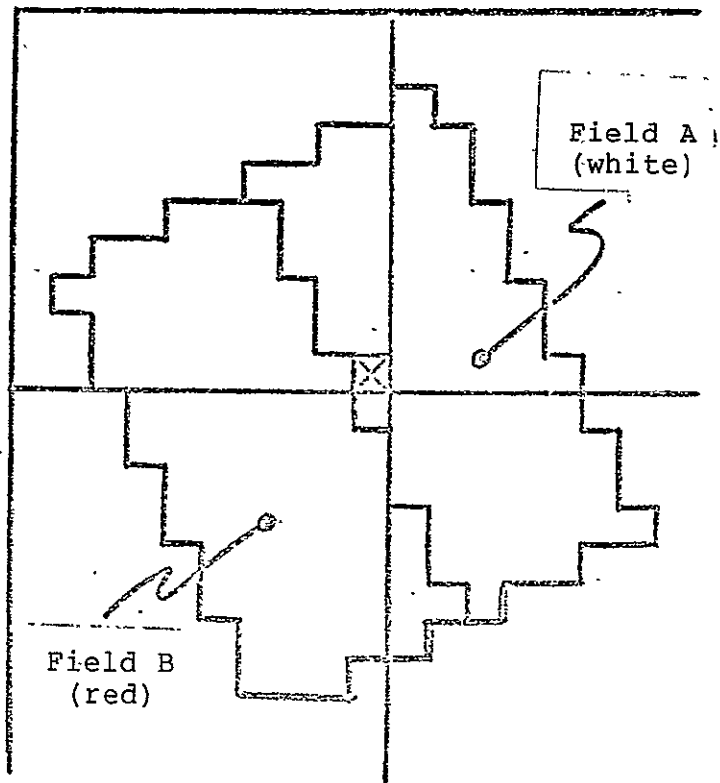


Figure 5.- Relationship between a dot and a field.

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The determination of pure, mixed or misregistered should be recorded on the labeling form as shown in Figure 6. (P-pure, M-mixed, R-misregistered) If a dot is found to be mixed, record the coordinates of an interior pixel from the field with which the dot is associated.

If a dot is obscured by clouds, cloud shadows or haze on any of the selected acquisitions, leave the pure, mixed, misregistered column (column 13) blank and record a U in the final label column (column 47).

[illegible]

Figure 6.- Recording of pure, mixed, and misregistered dots.

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5. Separate pure dots into cropland or non-cropland
Using the acquisitions selected from windows,

execute the decision logic shown in Figure 7 for each pure dot recording your responses in columns 15 thru 19 of the labeling form as shown in Figure 8 (Y=yes, N=no).

If the decision logic indicates that the dot is non-cropland, a D should be entered in the first label column (column 45). If the dot is cropland, column 45 should be left blank at this point.

The decision logic in Figure 7 is a portion of the Decision Logic for Major Land-Use Categories (Figure 9) which has been slightly modified for this procedure. The complete Decision Logic for Major Land-Use Categories can be found in Appendix B of the Detailed Analysis Procedures for Transition Project (FY79).

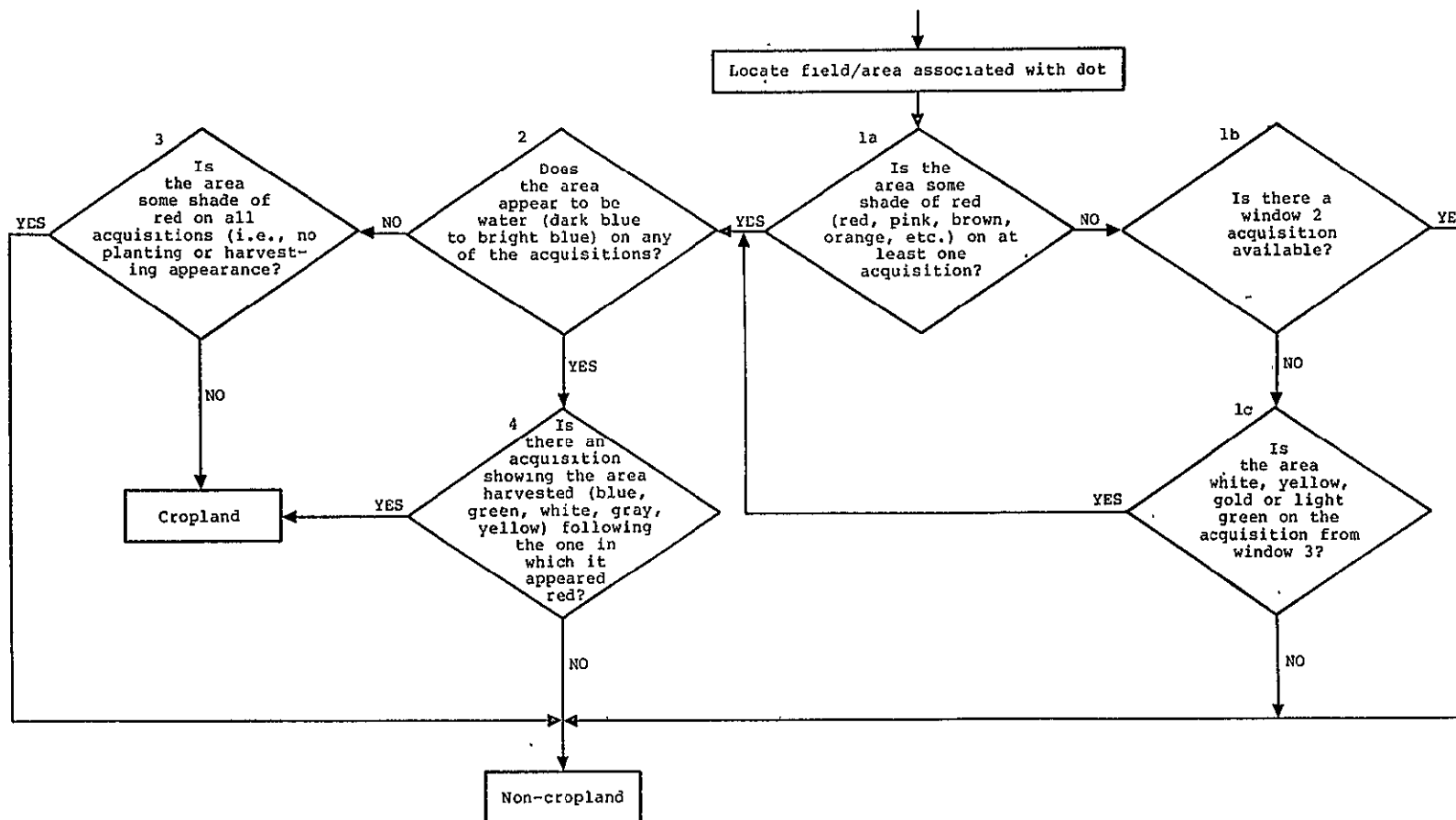
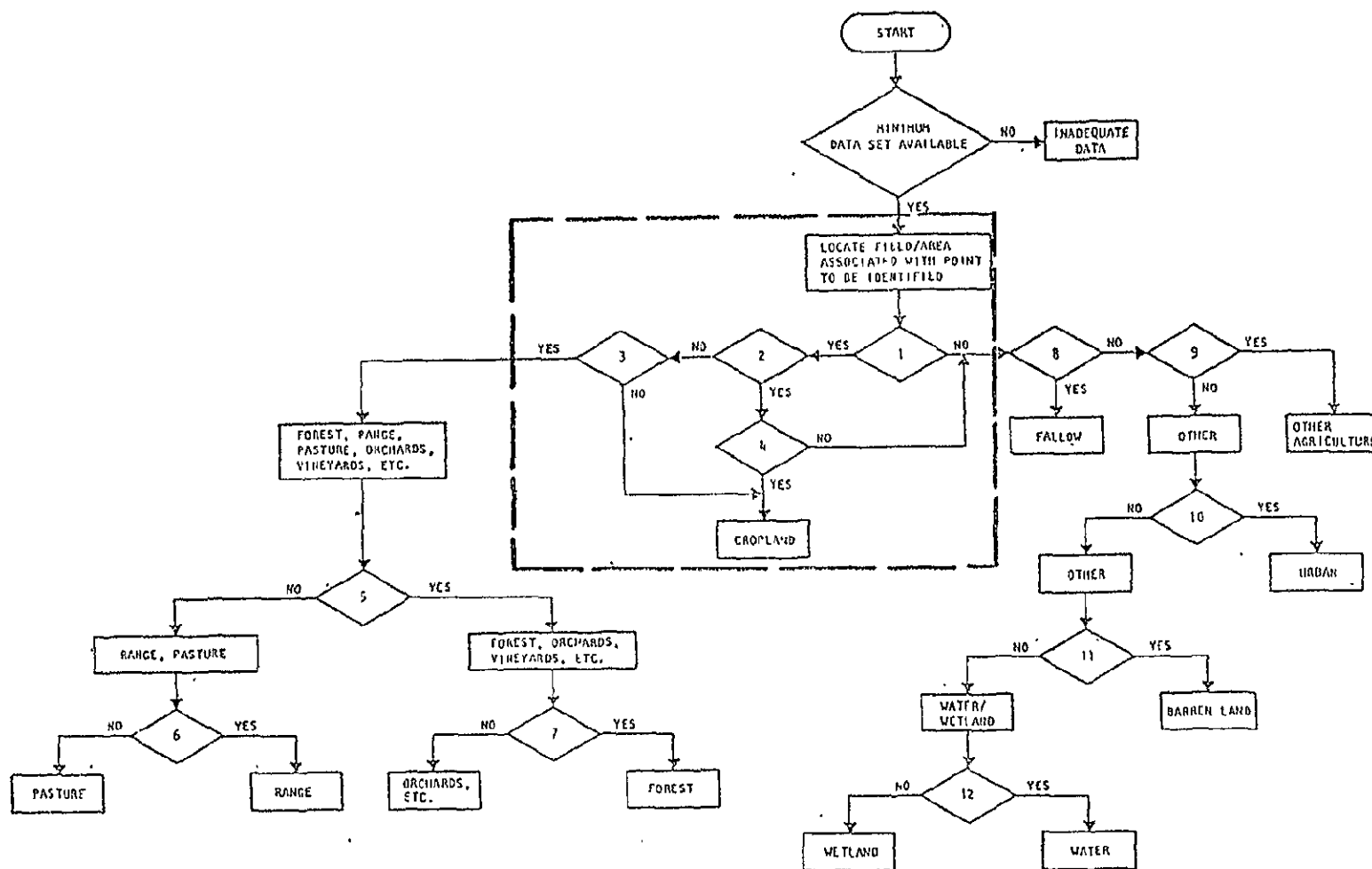


Figure 7.- Decision Logic for Cropland - Non-cropland.

[illegible]



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Figure 9. Diagram of decision tree for major land-use categories.

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6. Separate pure cropland dots into spring small grains and non-spring small grains.

For those pure dots determined to be cropland, execute the decision logic in Figure 10.

Those pure cropland dots which meet the green number/brightness criteria for spring small grains on the acquisitions selected from windows are subjected to a final test by requiring that the green number be less than 20 on all acquisitions collected during time period A. If the green number is not usable on these acquisitions due to misregistration, the dot should be reserved for labeling along with the mixed and misregistered dots.

The green numbers/brightness values which are used in making the decisions should be recorded in columns 20 thru 43 of the labeling form as shown in Figure 11. The labels of S for spring small grains and N for non-spring small grains should be recorded in column 45.

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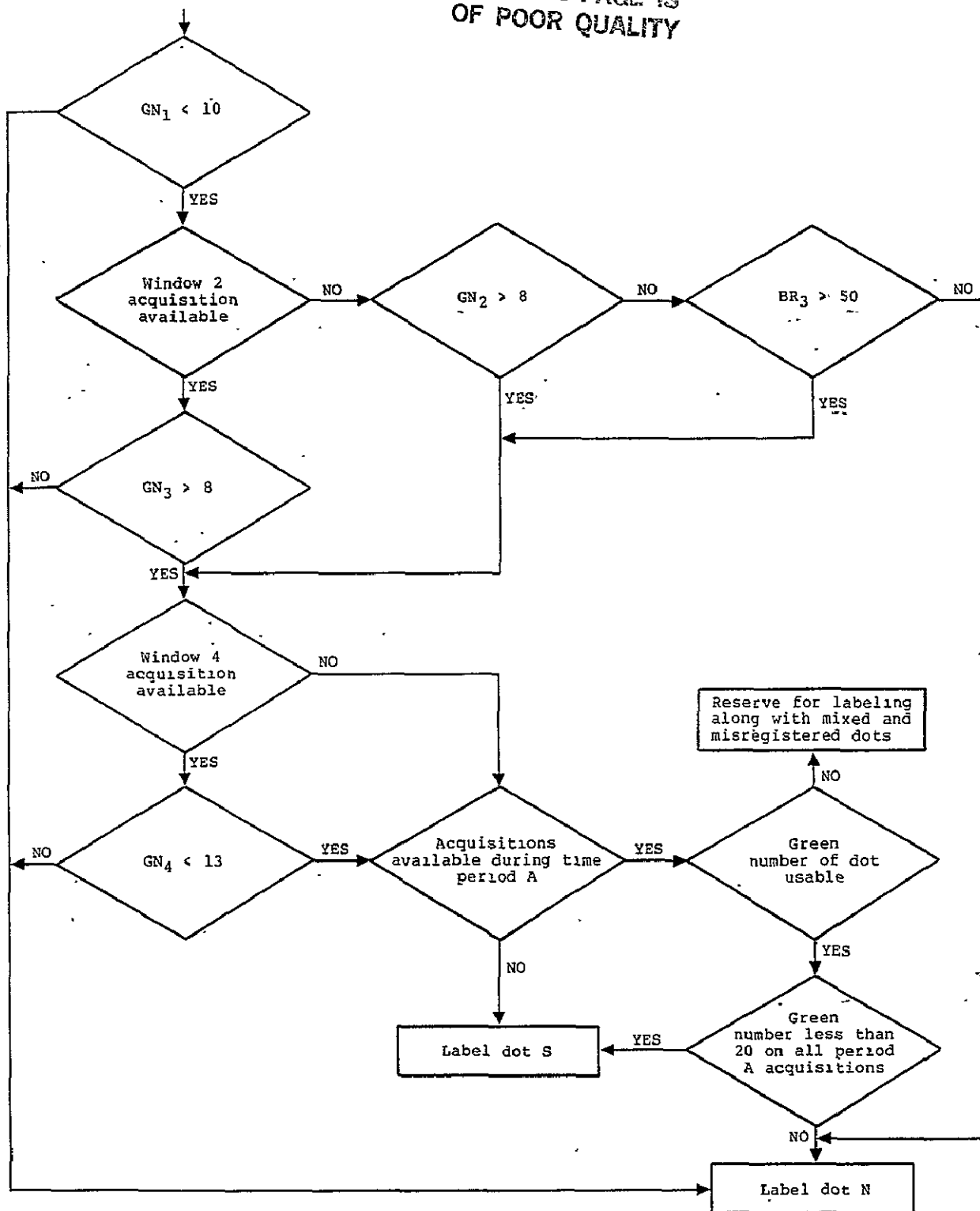


Figure 10.- Decision Logic for pure cropland dots.

Figure 11.- Recording of pure cropland dots as spring small grains or non-spring small grains.

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7. Label Mixed, Misregistered and Reserved Dots by comparing to Pure Dots.

Delineate and annotate enough of the fields/areas associated with dots which have been labeled D, N or S to provide a representative cross section of each class. Compare the imagery appearance (Product 1)* of each field/area associated with a mixed, misregistered or reserved dot to the annotated fields/areas and select the field/area which is most similar in appearance. Record the label of the selected field/area for the mixed, misregistered or reserved dot. Record the labels in column 45 of the labeling form as shown in Figure 12.

* For instructions on the use of Product 3, refer to the Detailed Analysis Procedures for Transition Project (FY79).

[illegible]

Figure 12.--Recording of mixed, registered, and reserved dots as D, S, or N.

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8. Label each spring small grain dot as B, S, Q or V.

In column 46 of the labeling form, record one of the following labels for each spring small grain dot.

(The recording is illustrated in Figure 13.)

- B - (barley) - spring small grains in the more advanced growth stages. (bright pink, yellow, bright gold, tan, white, light gray, light green on Product 1 from window 3)*
- S - (spring wheat, oats, flax) - spring small grains in the least advanced stages. (red, brown, reddish brown on Product 1 from window 3)*
- Q - spring small grains which appear to be between the groups labeled B and S. Some spring wheat/oats fields may be at the soft dough or ripe stages as illustrated in Figure 14. They will not have a bright appearance but otherwise may be confused with barley. Dots which fall into fields such as this should be labeled Q.
- V - spring small grains dots which were determined to be mixed unless they are associated with a field containing a dot labeled B or S. If they are, they should receive the same label as the pure dot.

* For instructions on the use of Product 3, refer to the Detailed Analysis Procedures for Transition Project (FY79).

Dot no.				Line				Pixel				P M or R	Responses to questions from decision logic for major landuse categories				Green numbers from time period A acquisitions												Label			Coordinates of interior pixel from field/area associated with mixed dot												Segment number																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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Figure 13.- Recording of labels for scatter plot generation.

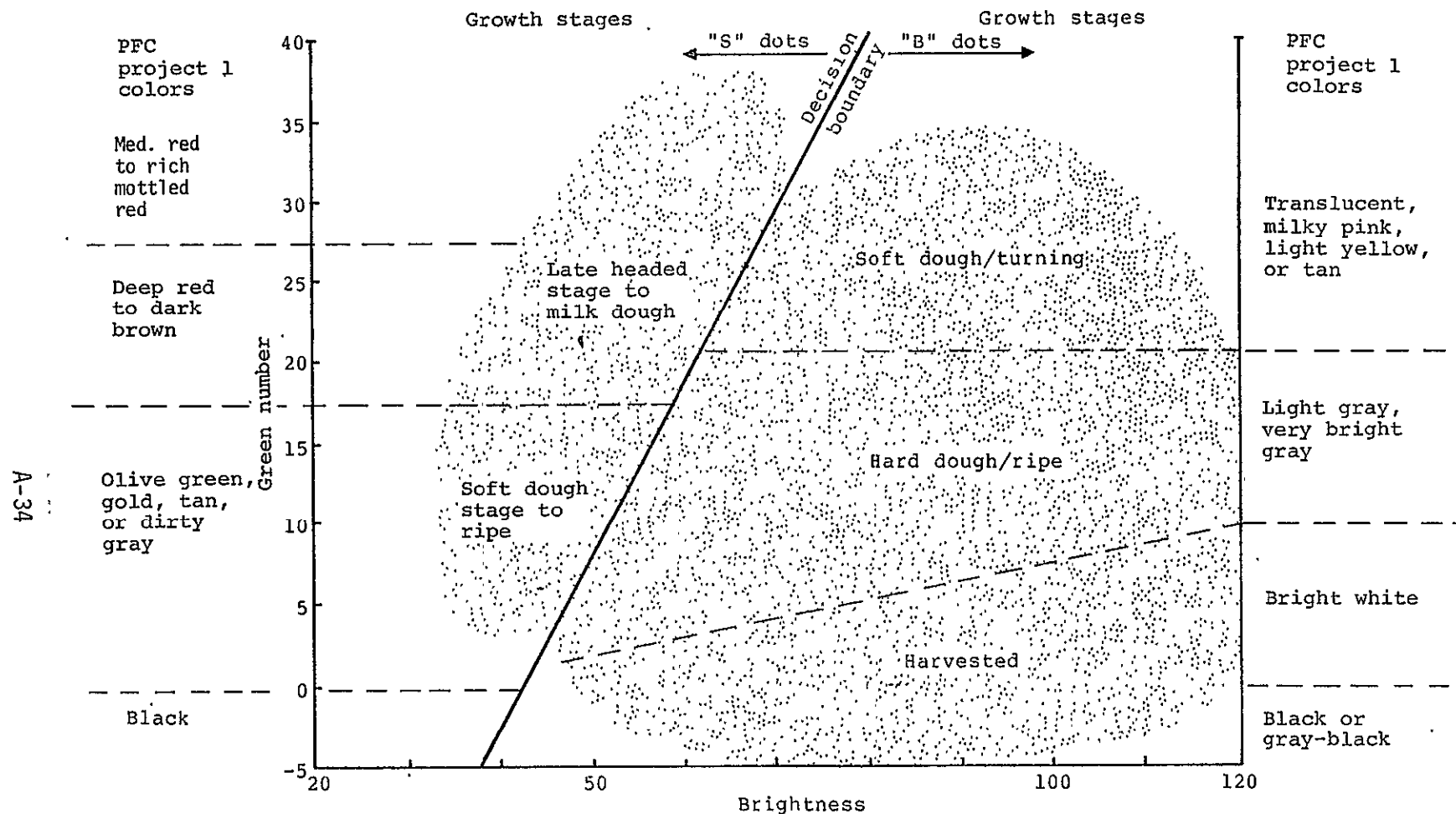


Figure 14.- General relationship between image appearance/growth stage and location on scatterplot generated from window 3 acquisition.

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9. Generate a green number versus brightness scatter plot of the E.S.Q and V dots using the window 3 acquisition.

Transfer the labels from column 46 of the labeling form to a Process Request Form and generate a green number versus brightness scatter plot using the window 3 acquisition. If a window 2 acquisition is available, request green number versus brightness trajectory plots using the acquisitions from windows 2 and 3. (Additional acquisitions up to a total of eight may be included.)

The relationship between the location of a dot on the scatter plot and imagery color/growth stage is generally as shown in Figure 14. The barley dots will fall to the right of the decision line and be widely scattered. The other spring small grains will form a relatively tight cluster in the region noted as late headed to milk dough.

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10. Determine Decision Line.

If there are B and S dots, construct a line on the scatter plot of the form $GN = 1.1 BR + \text{constant}$ through the S dot where the constant is a minimum and no pure B dots fall to the left of the line (Line A). Construct a line of the form $GN = 1.1 BR + \text{constant}$ through the B dot where the constant is a maximum and no pure S dots fall to the right of the line (Line B). (A template is provided to assist in constructing these lines.)

If the location of the dots is such that a line cannot be constructed, reexamine the image appearance of the dot(s) which prevent construction of the line. If the original label(s) were in error, change the label(s) and continue. If the original label(s) are confirmed, place the line just to the right of the rightmost S dot in the case of Line B or just to the left of the leftmost B dot in the case of Line A.

If a window 2 acquisition is available, green number versus brightness trajectory plots will be used to assist in determining the decision line. Generally in the time period from window 2 to window 3, barley dots become less green but brighter. The dot drift or direction of movement on the trajectory plot will be down and to the right. During this same period, spring wheat and oats dots become less green and less bright. The dot drift will be down and to the left.

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If a window 2 acquisition is available, transfer the dot drift from the green number versus brightness trajectory plots to the scatter plot for each dot between lines A and B. Place the decision line parallel to and between lines A and B such that dots having different drift characteristics are separated. An example of this is shown in Figure 15.

If a window 2 acquisition is not available, place the decision line between and parallel to lines A and B such that 1) No dots to the right of the line appear to group with the S dots and 2) Dots to the right of the line are widely scattered as opposed to the closer knit group to the left of the line.

This technique is illustrated in Figure 16.

If no dots were labeled B, construct Line A. If window 2 acquisition is available, check the dot drift of dots which fall to the right of the line to determine if they behave more like barley (increase in brightness with decrease in green number) or spring wheat (decrease in brightness with decrease in green number). Use the dot drift, scatter as opposed to clustering and Figure 14 to determine if Line A should be the decision line or it should be to the right of and parallel to Line A. If no dots were labeled S, construct Line B. Use the same technique described above to determine if Line B should be the decision line or whether it should be placed to the left of and parallel to Line B.

Green number

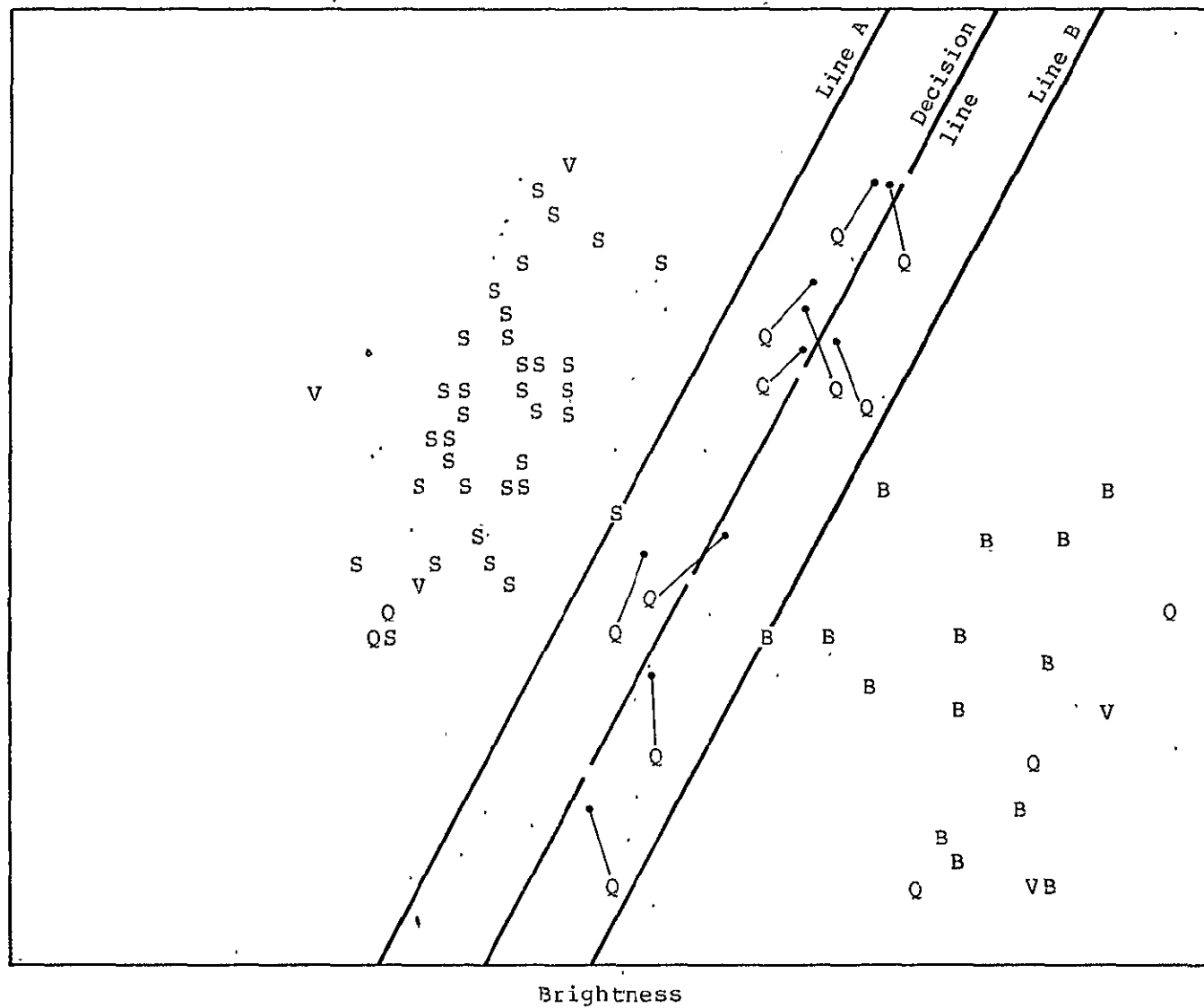
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Figure 15.- Illustration of the use of dot drift characteristics to determine decision line.

Green number

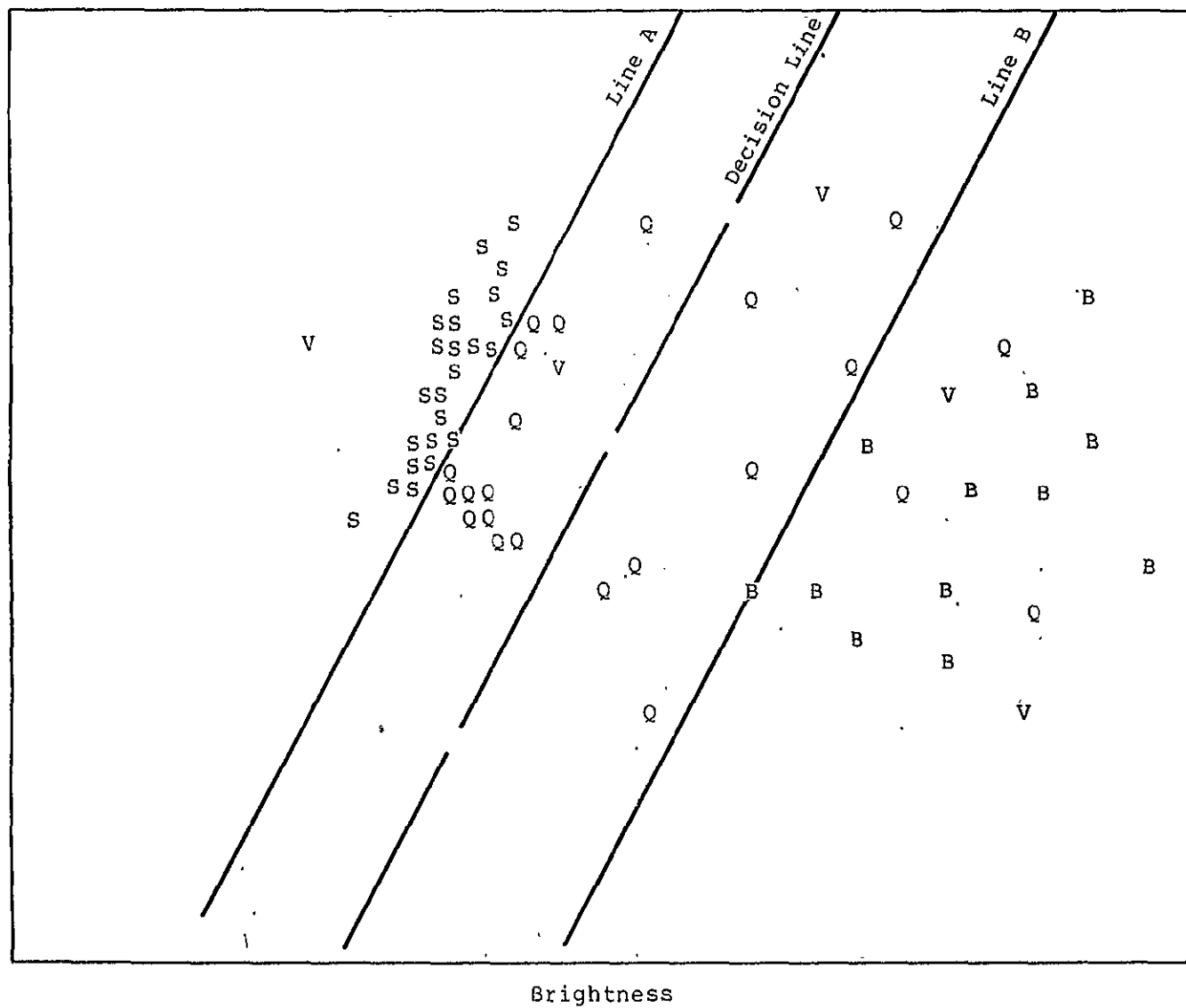
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Figure 16.- Illustration of the determination of
decision line without a window 2 acquisition.

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11. Relabel Dots according to location of decision line.

All Q and V dots which fall to the right of the decision line should be labeled B in the final label column.

All Q and V dots which fall to the left of the decision line should be labeled S in the final label column.

The original interpretation should be confirmed for any pure B dots which fall to the left of the line and any pure S dots which fall to the right of the line.

Final labels should be recorded on the labeling form in column 47 as shown in Figure 17.

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Dot no.	Line	Pixel	Responses to questions from decision logic for referent categories				Gross numbers from time period A acquisitions				Label	Coordinates of interior pixel from field/area associated with mixed dot		Segment number
			1a	1b	1c	2 or 4	GN ₁	GN ₂	GN ₃	BR ₃		GN ₄	Line	
1	1	10												
2	2	10												
3	3	10												
4	4	10												
5	5	10												
6	6	10												
7	7	10												
8	8	10												
9	9	10												
10	10	10												
11	11	10												
12	12	10												
13	13	10												
14	14	10												
15	15	10												
16	16	10												
17	17	10												
18	18	10												
19	19	10												

Figure 17.- Recording of final labels.

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